Introduction

The first procedure when a dentist treats a patient with crowns or bridges is to reduce the teeth to a precisely defined shape. Of particular importance is the angle of taper or convergence between opposing walls. These convergence angles $\theta_1$ and $\theta_2$, and alignment angles $\theta_3$ and $\theta_4$, are shown in Fig. 1. Excessive convergence reduces retention whereas undercutting makes the fabrication of acceptable cast restorations impossible.

The recommended taper between opposing walls is $6^\circ$ (Shillingburg et al., 1981; Dykema et al., 1986), and, in the case of a bridge, the alignment of abutment teeth provides a clear path of insertion. This may be achieved by using a rotary cutting instrument, or bur, with a $6^\circ$ taper and keeping it parallel to the long axis of the tooth when preparing the walls.

In practice, a closely controlled angle is difficult to achieve. Ohm and Silness (1978) measured the convergence angles of casts of teeth sent to commercial laboratories and found that most fell into the range 12-37°.

A number of paralleling devices have been described in the dental literature, which are either parallel linkages (Solle, 1961; Jermy, 1962a, b; Kopsiaftis, 1966; De Rezende, 1969; Karlstrom, 1971; Goransson and Parmlid, 1975; Gold, 1985) which constrain handpiece movement or visual alignment guides (Bottger, 1969; O'Meeghan and Behrend, 1983; Thompson, 1967; Gamet and Zusman, 1965). Linkages are awkward and time consuming to use and intimidating to the patient. Visual guides do not indicate when the alignment is outside a specified tolerance and the dentist's attention is divided between the device and the tooth.

This note describes an alignment device designed to overcome these problems.

Method

An electronic alignment indicator (The King's Inclinometer) was built with two electronic gravity-sensing transducers mounted on the rear of a dental handpiece (Rosenstiel and Deane, 1985). These sense handpiece alignment and eight LEDs on the turbine head indicate deviation from the required angular orientation. The device is attached to a standard handpiece which is mechanically unconstrained, as shown in Fig. 2.

To operate the device, the dentist first sets the sensor housing so it will be approximately vertical while the tooth is being prepared (within 20°). Then, with the bur at the correct orientation, the device is zeroed by operating a footswitch connected to a control unit. The system then records the selected orientation as measured by the sensors.
If the handpiece is tilted from the reference position by more than a tolerance value selected on the control unit the LEDs are activated. These indicate the direction of tilt by emitting steady or flashing lights. A flashing LED pair indicates that the tip of the bur has to be tilted away from it to correct the deviation and a steady pair means the bur has to be tilted towards it.

The sensor axes X and Y are parallel to the pairs of LEDs AA', BB' and CC', DD', respectively. The system schematic is shown in Fig. 3. With the device it is not necessary to divert attention from the tip of the bur during tooth preparation, since at least one of the LEDs lies in the immediate peripheral vision and only flashes when the bur orientation goes out of tolerance.

The sensors, capacitive devices (type L212, from G&G Technics, Lupsingen, Switzerland), were connected to sensor modules from the same supplier, giving a voltage output proportional to tilt. Signal-conditioning amplifiers apply a gain and offset to the signal from each sensor. When the footswitch is pressed and released, the inputs $V_x$ and $V_y$ are captured and held as reference voltages $V_{xR}$ and $V_{yR}$. For droop-free operation the sample-and-hold circuit used for storing the reference voltages was built using a digital-to-analogue convertor driven from a counter, control logic and a comparator. In sample mode the convertor output ramps up to the input voltage, at which point the comparator triggers the logic to freeze the counter. The output is taken from the convertor.

The sensitivity control potentiometer gives an output voltage which is used to generate the threshold voltages above and below each reference voltage by the summing amplifiers. A set of voltage comparators compares the signal voltage for each channel with the threshold levels and if the signal crosses either threshold then the appropriate combination of LEDs is illuminated via the control logic. The clock circuit generates the signal for flashing the appropriate LED pairs. The sensitivity control potentiometer gives an output voltage for ease of use and for accuracy of the preparation.

Two limitations of the prototype hardware are that the LED assembly was not sterilisable and therefore could not be used clinically and use of the indicator was limited to mandibular jaw preparations (i.e. with the bur tip pointing downwards). A microprocessor-based version of the system is being developed which will overcome these drawbacks and will also provide the alternative of audio feedback.

3 Evaluation

A pilot laboratory evaluation was carried out to determine if the system is effective in improving taper generation and to determine the acceptability of the system to dentists. Extracted teeth (two second premolars and two second molars) were mounted in plaster in a mannequin head. Ten dentists were each asked to prepare two pairs of teeth as for a bridge, one pair using the device and the contralateral pair without. A short questionnaire was also given to provide information on the participants' subjective evaluation of its usefulness, whether they would like such a system, and any specific comments. A travelling microscope (Maxtascan from Graticules Ltd., Tonbridge) linked to a computer was used to measure the convergence of individual teeth, and alignment between corresponding walls of adjacent teeth.

The mean value of the convergence angle without the device was 11.9º and for the alignment angle also 11.9º. With the device the mean convergence angle was reduced to 8.3º and alignment angle to 8.4º. The pooled standard deviation of the samples was 3.5º. The improvement is statistically significant at the $p < 0.001$ level.

Of the nine dentists who completed the questionnaire all thought the device would help overcome alignment problems in fixed prosthodontics to a greater or lesser extent and all liked the feedback and zeroing mechanisms. One dentist disliked using the device.

4 Discussion

The inclinometer described provides an effective means for improving crown and bridge preparation which is acceptable to the dentist and does not interfere with the normal mode of working.

The laboratory evaluation with the teeth rigidly mounted gave no indication of the effect that patient jaw movement would have on the results obtained in clinical use. Provided the device is periodically reset against a reference tooth surface it should be possible to minimise the effect of jaw movement. This is to be investigated in a clinical trial, along with optimisation of the sensitivity angle for ease of use and for accuracy of the preparation.

References


Fig. 3 System block diagram